XI. *Obſervations and Experiments on the Light of Bodies in a State of Combuſtion. By the Rev. Mr.* Morgan ; *communicated by the Rev.* Richard Price, *LL.D. F.R.S.*

Read January 27, 1785.

THE diſcuſſion which I now wiſh to lay before the Royal Society is nothing more than a ſeries of facts, and of concluſions which ſeem to flow from thoſe facts, and from an attention to the following data.

I. That light is a body, and like all other bodies ſubject to the laws of attraction.

II. That light is an heterogeneous body, and that the ſame attractive power operates with different degrees of force on its different parts.

III. That the light which eſcapes from combuſtibles when decompoſed by heat, or by any other means, was, previous to its eſcape, a component part of thoſe ſubſtances.

It is an obvious concluſion from theſe data, that when the attractive force, by which the ſeveral rays of light are attached to a body, is weakened, ſome of thoſe rays will eſcape

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eſcape ſooner than others. Thoſe which are united with the leaſt degree of power will eſcape firſt, and thoſe which adhere to it moſt ſtrongly will (if I may be allowed the expreſſion) be the laſt to quit their baſis. We may here have recourſe to a familiar fact, which is analogous to this, and will illuſtrate it. If a mixture, conſiſting of equal parts of water, of ſpirits of wine, and of other more fixed bodies, be placed over a fire; the firſt influence of that heat, to which all the ingredients are alike expoſed, will carry off the ſpirits of wine only. The next will carry off the ſpirits of wine blended with particles of water. A ſtill greater degree of heat will blend with the vapour which eſcapes a part of the more fixed bodies, till at length what evaporates will be a mixture of all the ingredients which were at firſt expoſed to the fire. In like manner, when the ſurface of a combuſtible is in a ſtate of decompoſition, thoſe parts which are the leaſt fixed, or which are united to it with the leaſt force, will be ſeparated firſt. Amongſt theſe the indigo rays of light will make the earlieſt appearance. By increaſing the heat we ſhall mix the violet with the indigo. By increaſing it ſtill more we ſhall add the blue and the green to the mixture, till at length we reach that intenſity of heat which will cauſe all the rays to eſcape at the ſame inſtant, and make the flame of a combuſtible perfectly white. It is not my preſent deſign to ſhew why the moſt refrangible rays are the firſt which eſcape from a burning body, but to enumerate the ſeveral facts which ſeem to ſhew, that ſuch a general law takes place in combuſtion; and that the various colours of bodies in this ſtate are uniformly regulated by that decreaſe of attractive force now deſcribed.

By examining the flame of a common candle we may obſerve, that its loweſt extremities, or the part in which the black colour of the wick terminates, diſcharges the leaſt heat; and that, as the vertex of the flame is approached, a ſucceſſive order of parts is paſſed through, in which the loweſt is continually adding to the heat of what is juſt above it, till we come to the top of the flame, near which all the heat is collected into a focus. At the loweſt extremity, however, where the heat is inconſiderable, a blue colour may be always obſerved; and from this appearance, amongſt others, it may, I think, be ſafely concluded, that the blue rays are ſome of thoſe which eſcape from combuſtibles in an early period of their decompoſition; and that if the decompoſition could be examined in a period ſtill more early, the colour of their flame would be violet. By an *a priori* deduction of this kind, I was led to watch the appearances of a candle more attentively; whence I found that to the external boundary of a common candle is annexed a filament of light, which, if proper care be taken to prevent the eſcape of too much ſmoke, will appear moſt beautifully coloured with the violet and indigo rays. To the preceding inſtance of a common candle many facts may be added, which ſpeak a ſimilar language. If ſulphur or æther is burned, or any of thoſe combuſtibles whoſe vapour is kindled in a ſmall degree of heat, a blue flame will appear, which, if examined by the priſm, will be found to conſiſt of the violet, the indigo, the blue, and ſometimes a ſmall quantity of the green rays. The beſt mode, however, of ſhewing the eſcape of ſome rays by that degree of heat which will not ſeparate others till increaſed, is the following. Give a piece of brown paper a ſpherical form, by preſſing it upon any hard globular ſubſtance. Gradually bring the paper, thus formed, to that diſtance from the candle at which it will begin to take fire. In this caſe a beautiful blue flame may be ſeen, hanging as it were by the paper till a hole is made in it, when the flame, owing to the increaſed action of the air upon all parts of it, becomes white, though the edges ſtill continue of a blue or violet colour. As a confirmation of what I have concluded from the preceding facts, it may be obſerved, that the very flame which, when expoſed to a certain degree of heat, emitted the moſt refrangible rays only, will, if expoſed to a greater degree of heat, emit ſuch as are leſs refrangible. The flames of ſulphur, ſpirits of wine, &c. when ſuddenly expoſed to the heat of a reverberatory, change their blue appearance for that which is perfectly white. But to gain a more ſtriking diverſity of this fact, I adopted Mr. MELVILL's mode of examining bodies whilſt on fire. I darkened my room, and placed between my eye and the combuſtible a ſheet of paſteboard, in the center of which I made a ſmall perforation. As the light of the burning body eſcaped through this perforation, I examined it with a priſm, and obſerved the following appearances. When the ſpirits of wine were ſet on fire, all the rays appeared in the perforation; but the violet, the blue, and the green, in the greateſt abundance. When the combuſtion of the ſpirits was checked by throwing ſome ſal ammoniac into the mixture, the red rays diſappeared; but when, by the long continuance of the flame, the ſal ammoniac was rendered ſo hot as to increaſe, rather than diminiſh the combuſtion, the red rays again appeared at the perforation. If the ſcreen was managed ſo that the different parts of the flame might be examined ſeparately, I always obſerved that the colours varied according to the degree of heat. At the baſe of the flame, or where the heat was leaſt, the indigo, the violet, and a very ſmall tinge of the blue and green appeared. As I approached the vertex of the flame, the rays which eſcaped became more and more numerous till I reached the top, when all the rays appeared in the priſm. It ſhould be attended to, that when the red rays firſt made their appearance, their quantity was ſmall, and gradually increaſed as the eye in its examination approached that part where the heat was greateſt. Mr. MELVILL, when he made ſome of the preceding experiments, obſerved, that the yellow rays frequently eſcaped in the greateſt abundance; but this ſingularity proceeded from ſome circumſtances which eſcaped his attention. In conſequence of mixing acids or ſalts with the burning ſpirits, a very denſe fume of unignited particles ariſes, and before the rays of the burning body arrive at the perforation where the priſm catches them, they muſt paſs through a medium which will abſorb a great part of the indigo and the violet. On the other hand, owing to the imperfection of the decompoſition, very few of the red rays are ſeparated from their baſis, and conſequently the yellow and the orange rays are thoſe alone which paſs through the unburnt ſmoke of the flame.

I would now proceed with obſerving, that, beſides the increaſe or decreaſe of heat, there are other modes of retarding or accelerating the combuſtion of bodies, by which alſo may be examined ſome of the preceding illuſtrations.

1. A candle burns moſt rapidly and brilliantly in dephlogiſticated air.

2. The blue colour of a ſulphureous flame in pure air is changed into a dazzling white.

3. The flame of inflammable air, when mixed with nitrous air, is green. It is white ſtrongly tinged with the indigo and violet when mixed with common air; but when mixed with dephlogiſticated air, or ſurrounded by it, the brilliancy of its flame is moſt ſingularly beautiful.

If the preceding facts prove that light, as an heterogeneous body, is gradually decompoſed during combuſtion; if they prove, likewiſe, that the indigo rays eſcape with the leaſt heat, and the red with the greateſt; I think we may rationally account for ſeveral ſingularities in the colours of different flames. If a piece of paper, impregnated with a ſolution of copper in the nitrous acid, be ſet on fire, the bottom and ſides of the flame are always tinged with green. Now this flame is evidently in that weak ſtate of decompoſition, in which the moſt refrangible rays eſcape in the greateſt abundance; but of theſe rays the green eſcape moſt plentifully through the unignited vapour and that portion of the atmoſphere which ſeparates the eye from the flame. The peculiarity which I have now endeavoured to account for may be obſerved in the greateſt perfection in braſs founderies. The heat in this inſtance, though very ſtrong, is ſcarcely adequate to the decompoſition of the metallic vapour which eſcapes from the melted braſs. A very ſingular flame therefore appears to the eye; for while its edges are green, its body is ſuch as to give the objects around a very pallid or ghaſtly appearance, which is the conſequence of its wanting that portion of red rays which is neceſſary to make a perfect white.

The moſt ſingular phænomenon attending a burning body is, perhaps, the red appearance it aſſumes in its laſt ſtage of combuſtion. The preceding facts and obſervations may, I think, help us to explain it.

1. After a body has continued to burn for ſome time, its external ſurface is to be regarded as having loſt a great portion if not the whole of thoſe rays which the firſt application of heat was able to ſeparate. But theſe rays were the indigo, the violet, the blue, and perhaps the green. Nothing, therefore, will remain to be ſeparated, but the yellow, the orange, and the red. Conſequently, the combuſtion of the body, in its laſt ſtate of decompoſition, can aſſume no other than a reddiſh appearance. But

2. Let us conſider the external ſurface of the combuſtible as annexed to an inner ſurface, which may be partly, but not ſo perfectly decompoſed as itſelf: for the violence of the heat will be found to leſſen in its effects the nearer it approaches to the center of the ſubſtance which is expoſed to it. Hence we are to conſider the parts which are juſt covered by the external ſurface as having loſt leſs of their component light than the external ſurface itſelf. Or the former may retain the green rays when the latter has loſt both indigo, violet, blue, and green.

3. Thoſe parts which are nearer the center of the body than either of the preceding muſt, as they are further from the greateſt violence of the heat, have loſt proportionably fewer of their rays. Or while the more external parts may have loſt all but the red, theſe may have loſt only the indigo and violet.

4. The moſt central parts may be unaffected by the heat; and whenever the fire does reach theſe parts, they will immediately diſcharge their indigo rays, and be decompoſed in the

gradual manner which I have already deſcribed. A piece of rotten wood, whilſt burning, will exemplify and confirm the preceding illuſtration. When influenced by the external air only, if examined through a priſm, no rays will be found to eſcape but the orange and the red. By blowing upon the burning wood with a pair of bellows, the combuſtion, being increaſed, will affect thoſe internal parts of the body which were not acted upon before. Theſe parts, therefore, will begin to loſe their light, and a priſm will ſhew the green, the blue, the violet, and indigo, all appearing in ſucceſſion. Appearances ſimilar to the preceding may be obſerved in a common kitchen fire. When it is fainteſt, its colour is moſt red, the other rays having been emitted, and the combuſtion at a ſtand; but by blowing upon it in this ſtate, its brightneſs will be increaſed, and more and more of the rays which are yielded by the internal parts of the body will come to the eye, till at length, by continuing to blow, the combuſtion will be made ſo complete as to yield all the rays, or to make it appear perfectly white.

Many are the varieties diſcoverable in the flames and in the appearances of fixed burning bodies to which the preceding obſervations may be applied; but, to avoid unneceſſary amplification I will take notice only of what appears to me an imperfection in Sir ISAAC NEWTON's definition of flame. He conjectures, that it may be a vapour heated red-hot. I think I ſhould rather ſay, that flame is an inſtance of combuſtion whoſe colour will be determined by the degree of decompoſition which takes place. If it be very imperfect, the moſt refrangible rays only will appear. If it be very perfect, all the rays will appear, and its flame will be brilliant in proportion to this perfection. There are flames, however, which conſiſt of burning particles, whoſe rays have partly eſcaped before they aſcended in the form of vapour. Such would be the flame of a red-hot coal, if expoſed to ſuch a heat as would gradually diſperſe it into vapour. When the fire is very low under the furnace of an iron foundery, at the upper orifice of the chimney a red flame of this kind may be ſeen, which is different from the flame that appears immediately after freſh coals have been thrown upon the fire; for, in conſequence of adding ſuch a ſupply to the burning fuel, a vaſt column of ſmoke aſcends, and forms a medium ſo thick as to abſorb moſt of the rays excepting the *red*.

Experiments on electric light.

If we would wiſh to procure any degree of certainty in any hypotheſis which we may form concerning electrical light, perhaps the following general deductions may be of ſome ſervice to us.

1. There is no fluid or ſolid body in its paſſage through which the electric fluid may not be made luminous. In water, ſpirits, oil, animal fluids of all kinds, the diſcharge of a Leyden phial of almoſt any ſize will appear very ſplendid, provided we take care to place them in the circuit, ſo that the fluid may not paſs through too great a quantity of them. My general method is to place the fluid, on which I mean to make the experiment, in a tube three-quarters of an inch in diameter, and four inches long. I ſtop up the orifices of the tube with two corks, through which I puſh two pointed wires, ſo that the points may approach within one-eighth of an inch to each

other. The fluid in paſſing through the interval which ſeparates the wires is always luminous, if a force be uſed ſufficiently ſtrong. I ſhould obſerve, that the glaſs tube, if not very thick, always breaks when this experiment ſucceeds. To make the paſſage of the fluid luminous in the acids, they muſt be placed in capillary tubes, and two wires introduced, as in the preceding experiment, whoſe points ſhall be very near each other. It is a well known fact, that the diſcharge of a ſmall Leyden phial in paſſing over a ſtrip of gold, ſilver, or Dutch metal leaf, will appear very luminous. By conveying the contents of a jar, meaſuring two gallons, over a ſtrip of gold leaf one-eighth of an inch in diameter, and a yard long, I have frequently given the whole a dazzling brightneſs. I cannot ſay, that a much greater length might not have been made very ſplendid, nor can I determine to what length the force of a battery might be made luminous in this manner. We may give this experiment a curious diverſity, by laying the gold or ſilver leaf on a piece of glaſs, and then placing the glaſs in water; for the whole gold leaf will appear moſt brilliantly luminous in the water by expoſing it, thus circumſtanced, to the exploſion of a battery.

2. The difficulty of making any quantity of the electrical fluid luminous in any body increaſes as the conducting power of that body increaſes.

EXP. I. In order to make the contents of a jar luminous in boiling water, a much higher charge is neceſſary than would be ſufficient to make it luminous in cold water, which is univerſally allowed to be the worſt conductor.

EXP. II. I have various reaſons for believing the acids to be very good conductors. If therefore into a tube, filled with water, and circumſtanced as I have already deſcribed, a few drops of either of the mineral acids are poured, it will be almoſt impoſſible to make the fluid luminous in its paſſage through the tube.

EXP. III. If a ſtring*, whoſe diameter is one-eighth of an inch and whoſe length is ſix or eight inches, is moiſtened with water, the contents of a jar will paſs through it luminouſly, but no ſuch appearance can be produced by any charge of the ſame jar, provided the ſame ſtring be moiſtened with one of the mineral acids. To the preceding inſtance we may add the various inſtances of metals which will conduct the electrical fluid without any appearance of light, in circumſtances the ſame with thoſe in which the ſame force would have appeared luminous in paſſing through other bodies whoſe conducting power is leſs. But I proceed to obſerve,

III. That the eaſe with which the electrical fluid is rendered luminous in any particular body is increaſed by increaſing the rarity of the body. The appearance of a ſpark or of the diſcharge of a Leyden phial, in rarefied air is well known. But we need not reſt the truth of the preceding obſervation on the ſeveral varieties of this fact; ſimilar phænomena attend the rarefaction of æther, of ſpirits of wine, and of water.

EXP. IV. Into the orifice of a tube, 48 inches long, and two-thirds of an inch in diameter, I cemented an iron ball, ſo as to bear the weight which preſſed upon it when I filled the tube with quickſilver, leaving only an interval at the open end, which contained a few drops of water. Having inverted the tube, and plunged the open end of it into a baſon of mercury, the mercury in the tube ſtood nearly half an inch lower than it did in a barometer at the ſame inſtant, owing to the vapour which was formed by the water. But through this rarefied water the electrical ſpark paſſed as luminouſly as it does through air equally rarefied.

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* The thickneſs and diameter of the ſtring ſhould be regulated by the force we employ.

EXP. V. If, inſtead of water, a few drops of ſpirits of wine are placed on the ſurface of the mercury, phænomena ſimilar to thoſe of the preceding experiment will be diſcovered, with this difference only, that as the vapour in this caſe is more denſe, the electrical ſpark in its paſſage through it is not quite ſo luminous as it is in the vapour of water.

EXP. VI. Good æther ſubſtituted in the room of the ſpirits of wine will preſs the mercury down ſo low as the height of 16 or 17 inches. The electrical fluid in paſſing through this vapour (unleſs the force be very great indeed) is ſcarcely luminous. But if the preſſure on the ſurface of the mercury in the baſon be gradually leſſened by the aid of an air-pump, the vapour will become more and more rare, and the electric ſpark in paſſing through it more and more luminous.

EXP. VII. I could not diſcover that any vapour eſcaped from the mineral acids when expoſed *in vacuo*. To give them, therefore, greater rarity or tenuity, I found different methods neceſſary. With a fine camel-hair pencil, dipped in the vitriolic, the nitrous, or the marine acid, I drew upon a piece of glaſs a line about one-eighth of an inch broad. In ſome inſtances I extended this line to the length of 27 inches, and found that the contents of an electric battery, conſiſting of 10 pint phials coated, would paſs over the whole length of this line with the greateſt brilliancy. If by widening the line, or by laying on a drop of the acid, its quantity was increaſed in any particular part, the charge, in paſſing through that part, never appeared luminous. Water, ſpirits of wine, circumſtanced ſimilarly to the acids in the preceding experiment, were attended with ſimilar, but not equal effects, becauſe, in conſequence of the inferiority of their conducting power, it was neceſſary to make the line through which the charge paſſed conſiderably ſhorter.

4. The brilliancy or ſplendor of the electric fluid in its paſſage through any body is always increaſed by leſſening the dimenſions of that body. I would explain my meaning by ſaying, that a ſpark, or the diſcharge of a battery which we might ſuppoſe equal to a ſphere one quarter of an inch in diameter, would appear much more brilliant if the ſame quantity of fluid is compreſſed into a ſphere one-eighth of an inch in diameter. This obſervation is the obvious conſequence of many known facts. If the machine be large enough to afford a ſpark whoſe length is nine or ten inches, this ſpark may be ſeen ſometimes forming itſelf into a bruſh, in which ſtate it occupies more room, but appears very faintly luminous. At other times the ſame ſpark may be ſeen dividing itſelf into a variety of ramifications which ſhoot into the ſurrounding air. In this caſe, likewiſe, the fluid is diffuſed over a large ſurface, and in proportion to the extent of that ſurface, ſo is the faintneſs of the appearance. A ſpark, which in the open air cannot exceed one quarter of an inch in diameter, will appear to fill the whole of an exhauſted receiver four inches wide and eight inches long. But in the former caſe it is brilliant, and in the latter it grows fainter and fainter as the ſize of the receiver increaſes. To prove the obſervation, which I think may be juſtified by the preceding facts, I made the following experiments.

EXP. VIII. To an inſulated ball, four inches in diameter, I fixed a ſilver thread, about four yards long. This thread, at the end which was remoteſt from the ball, was fixed to another inſulated ſubſtance. I brought the ball within the ſtriking diſtance of my conductor, and the ſpark in paſſing from the conductor to the ball appeared very brilliant; but the whole length of the ſilver thread appeared faintly luminous at the ſame inſtant. In other words, when the ſpark was confined within the dimenſions of a ſphere one-eighth of an inch in diameter, it was bright, but, when diffuſed over the ſurface of air which received it from the thread, its light became ſo faint as to be ſeen only in a dark room. If I leſſened the ſurface of air which received the ſpark by ſhortening the thread, I never failed to increaſe the brightneſs of the appearance.

EXP. IX. To prove that the faintneſs of the electric light *in vacuo* depends on the enlarged dimenſions of the ſpace through which it is diffuſed, we have nothing more to do than to introduce two pointed wires into the vacuum, ſo that the fluid may paſs from the point of the one to the point of the other, when the diſtance between them is not more than the one-tenth of an inch. In this caſe we ſhall find a brilliancy as great as in the open air.

EXP. X. Into a Torricellian vacuum, 36 inches in length, I conveyed as much air as would have filled two inches only of the exhauſted tube, if it were inverted in water. This quantity of air afforded reſiſtance enough to condenſe the fluid as it paſſed through the tube into a ſpark 38 inches in length. The brilliancy of the ſpark in condenſed air, in water, and in all ſubſtances through which it paſſes with difficulty, depends on principles ſimilar to thoſe which account for the preceding facts. I would now proceed to ſhew,

5. That in the appearances of electricity, as well as in thoſe of burning bodies, there are caſes in which all the rays of light do not eſcape; and that the moſt refrangible rays are thoſe

which eſcape firſt or moſt eaſily. The electrical bruſh is always of a purple or bluiſh hue. If you convey a ſpark through a Torricellian vacuum, made * *without* boiling the mercury in the tube, the bruſh will diſplay the indigo rays. The ſpark, however, may be divided and weakened even in the open air, ſo as to yield the moſt refrangible rays only.

EXP. XI. To an inſulated metallic ball, four inches in diameter, I fixed a wire a foot and a half long. This wire terminated in four ramifications, each of which was fixed to a metallic ball half an inch in diameter, and placed at an equal diſtance from a metallic plate, which communicated by metallic conductors with the ground. A powerful ſpark, after falling on the large ball at one extremity of the wire, was divided in its paſſage from the four ſmall balls to the metallic plate. When I examined this diviſion of the fluid in a dark room, I diſcovered ſome little ramifications which yielded the indigo rays only: indeed, at the edges of all weak ſparks the ſame purple appearance may be diſcovered. We may likewiſe obſerve, that the nearer we approach the center of the ſpark, the greater is the brilliancy of its colour. But I would now wiſh to ſhew

6. That the influence of different media on electrical light is analogous to their influence on ſolar light, and will help us to account for ſome very ſingular appearances.

EXP. XII. Let a pointed wire, having a metallic ball fixed to one of its extremities, be forced obliquely into a piece of wood, ſo as to make a ſmall angle with the ſurface of the wood, and to make the point lie about one-eighth of an inch below the ſurface. Let another pointed wire, which communicates with the ground, be forced in the ſame manner into the ſame wood, ſo that its point likewiſe may lie about one-eighth of an inch below the ſurface, and about two inches diſtant from the point of the firſt wire. Let the wood be inſulated, and a ſtrong ſpark which ſtrikes on the metallic ball will force its paſſage through the interval of wood which lies between the points, and appear as red as blood. To prove that this appearance depends on the wood's abſorption of all the rays but the red, I would obſerve, that the greater the depth of the points is below the ſurface, the leſs mixed are the red rays. I have been able ſometimes, by increaſing or diminiſhing the depth of the points, to give the ſpark the following ſucceſſion of colours. When they were deepeſt below the ſurface, the red only came to the eye through a priſm. When they were raiſed a little nearer the ſurface, the red and orange appeared. When nearer ſtill, the yellow; and ſo on till, by making the ſpark paſs through the wood very near its ſurface, all the rays were at length able to reach the eye. If the points be only one-eighth of an inch below the ſurface of ſoft deal wood, the red, the orange, and the yellow rays will appear as the ſpark paſſes through it. But when the points are at an equal depth in a harder piece of wood (ſuch as box) the yellow, and perhaps the orange, will diſappear. As a farther proof that the phænomena I am deſcribing are owing to the interpoſition of the wood, as a medium which abſorbs ſome of the rays and ſuffers others to eſcape, it may be obſerved, that when the ſpark ſtrikes very brilliantly on one ſide of the piece of deal, on the other ſide it will appear very red. In like manner a red appearance may be given to a ſpark which ſtrikes brilliantly over the inſide of a tube, merely by ſpreading ſome pitch very thinly over the outſide of the ſame tube.

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* If the Torricellian vacuum is made with mercury perfectly purged of air, it becomes a perfect non-conductor. This, I believe, will be proved deciſively by ſome experiments which I hope will be ſoon communicated to the Royal Society.

DR. PRICE.

EXP. XIII. I would now give another fact, whoſe ſingularities depend very much on the influence of the medium through which the electrical light is made to paſs. If into a Torricellian vacuum, of any length, a few drops of æther are conveyed, and both ends of the vacuum are ſtopped up with metallic conductors, ſo that a ſpark may paſs through it, the ſpark in its paſſage will aſſume the following appearances. When the eye is placed cloſe to the tube, the ſpark will appear perfectly white. If the eye is removed to the diſtance of two yards, it will appear green; but at the diſtance of ſix or ſeven yards, the colour of the ſpark will be reddiſh. Theſe changes evidently depend on the quantity of medium through which the the light paſſes; and the red light more particularly, which we ſee at the greateſt diſtance from the tube, is accounted for on the ſame principle as the red light of a diſtant candle or a beclouded ſun.

EXP. XIV. Dr. PRIESTLEY long ago obſerved the red appearance of the ſpark when paſſing through inflammable air. But this appearance is very much diverſified by the quantity of medium, through which you look at the ſpark. When at a very conſiderable diſtance, the red comes to the eye unmixed; but, if the eye is placed cloſe to the tube, the ſpark appears white and brilliant. In confirmation, however, of ſome of my concluſions, I would obſerve, that by increaſing the quantity of fluid which is conveyed through any portion of inflammable air, or by condenſing that air, the ſpark may be entirely deprived of its red appearance, and made perfectly brilliant. I have only to add, that all weak exploſions and ſparks, when viewed at a diſtance, bear a reddiſh hue. Such are the exploſions which have paſſed through water, ſpirits of wine, or any bad conductor, when confined in a tube whoſe diameter is not more than an inch. The reaſon of theſe appearances ſeems to be, that the weaker the ſpark or exploſion is, the leſs is the light which eſcapes; and the more viſible the effect of any medium which has a power to abſorb ſome of that light.

The preceding obſervations concerning electrical light were the reſult of my attempts to arrange, under general heads, the principal ſingularities attending it. They may, perhaps, aſſiſt others in determining how far they may have led my mind aſtray in giving birth to a theory which I would now briefly deſcribe in a few queries.

I. If we conſider all bodies as compounds, whoſe conſtituent parts are kept together by attracting one another with different forces, can we avoid concluding, that the operations of that attractive force are regulated, not only by the quality, but the quantity likewiſe of thoſe component parts? If an union of a certain number of one kind of particles, with a certain number of a ſecond and third kind of particles, forms a particular body, muſt not the bond which keeps that body together be weakened or ſtrengthened by increaſing or diminiſhing any one of the different kinds of particles which enter into its conſtitution?

II. When, to the natural ſhare of the electric fluid already exiſting in the body, a freſh quantity of the ſame fluid is added, muſt not ſome of the component parts of that body eſcape; or muſt not that attractive force which kept all together be ſo far weakened as to let looſe ſome conſtituent parts, and amongſt theſe the particles of light in particular?

III. Muſt not this ſeparation of parts be great in proportion to the quantity of extraneous particles which are added to the body? Or (agreeable to the 4th obſervation) muſt not the ſpark be more ſplendid and brilliant, the more the electrical fluid is concentered in any given ſpace?

IV. In the diminution or alteration of that attractive force on which depends the conſtitution of bodies, may there not be a gradation which, in the preſent caſe, as well as in that of burning bodies, will cauſe the eſcape of ſome rays ſooner than others?

Obſervations on phoſphoric light.

It is obvious, from Mr. B. WILSON's experiments, that there are many curious diverſities in the appearances of phoſphori. Some ſhells, prepared agreeably to his directions, after expoſure to the ſun or to the flaſh of a battery, emit a purple, others a green, and others a reddiſh light. If with Mr. WILSON we ſuppoſe, that theſe ſhells are in a ſtate of ſlow combuſtion, may we not conclude, that ſome are juſt beginning to burn, and therefore, agreeably to what I have obſerved on combuſtible bodies, emitting the moſt refrangible rays; whilſt others are in a more advanced ſtate of combuſtion, and therefore emitting the leaſt refrangible. If this concluſion be right, the ſhells which are emitting the purple, or the green, muſt ſtill retain the yellow, the orange, and the red, which will alſo make their appearance as ſoon as the combuſtion is ſufficiently increaſed.

EXP. XV. Place a ſhell whilſt emitting its green rays on a warm ſhovel, and the appearance of the ſhell will be ſoon changed into that of a yellow mixed with red. To Mr. WILSON's theory, however, of ſlow combuſtion the following objections may be oppoſed.

1°. If phoſphoric ſhells owe their light to this cauſe, we muſt conſider the word combuſtion when applied to them as implying in its ſignification all thoſe circumſtances which are the uſual attendants of a body whilſt on fire. Amongſt other neceſſary conſequences in ſuch a caſe, the increaſe of heat muſt increaſe the decompoſition of the combuſtible; whereas we diſcover an effect the very oppoſite to this in the appearance of a phoſphoric body, which never fails to loſe its light entirely in a certain degree of heat, without loſing the power of becoming phoſphoric again when it has been ſufficiently cooled. Beſides, when a phoſphoric ſhell has been made very hot, and while it has continued ſo, I have conveyed the moſt brilliant diſcharge of a battery over it without effect. In other words, heat, or the very cauſe which promotes combuſtion in all other inſtances, in this particular caſe puts an end to it. Mr. WILSON, in his Treatiſe on Phoſphori, has deſcribed an experiment ſimilar to the preceding. But the reſult he mentions is different from that here mentioned. However, from a regard to his authority, I have ſo frequently repeated my trials that I cannot juſtly ſuſpect myſelf of any inaccuracy. 2°. When bodies are waſted by combuſtion, they can never be made to re-aſſume the appearances which they previouſly diſplayed. No power can give to aſhes the phænomena of a burning coal. But phoſphoric bodies are very different in this reſpect; for a ſhell may be made to loſe all its light by expoſure to heat, and again may be made as luminous as ever by expoſure to the ſun. But 3°. It is obſervable, that ſome bodies, which are moſt beautifully phoſphoric, or which, according to Mr. WILSON's theory, are in the beſt ſtate of ſlow combuſtion; it is obſervable, I ſay, that the ſame bodies are the moſt obſtinate in reſiſting the fire. The diamond, which to be decompoſed requires the force of a moſt powerful furnace, is, according to this theory, waſting away, owing to a ſeparation of parts which is promoted by the weakeſt influence of the ſun's rays.—Without determining whether the preceding objections be valid, let us now ſee the conſequence of admitting the common hypotheſis, that the detention of thoſe rays which fall upon phoſphori is owing to ſome force which prevents their immediate reflection, but is not adequate to their entire abſorption. This force, whatever it be, cannot well be ſuppoſed to operate with equal power on all the rays. And if this be not the caſe, I think we cannot avoid concluding, that phoſphoric ſhells will aſſume different colours, owing to the earlier and later eſcape of the different rays of light. This concluſion is juſtified by an experiment which I have already appealed to. When the force is ſuch as to admit of the eſcape of the purple, the blue, and the green, we have only to leſſen that force by warming the body, and the yellow, the orange, and red eſcape. It is proved by BECCARIA's extenſive experience on this ſubject, that there is ſcarcely any body which is not phoſphoric, or which may not be made ſo by heat. But as the phoſphoric force is moſt powerful when the purple rays only eſcape, ſo we are to conclude, that it is weakeſt when it is able to retain the red rays only. This concluſion is agreeable to ſeveral facts. Chalk, oyſter-ſhells, together with thoſe phoſphoric bodies whoſe goodneſs has been very much impaired by long keeping; when finely powdered and placed within the circuit of an electrical battery, will exhibit by their ſcattered particles a ſhower of light; but theſe particles will appear reddiſh, or their phoſphoric power will be ſufficient only to detain the yellow, orange, and red rays. When ſpirits of wine are in a ſimilar manner brought within the circuit of a battery, a ſimilar effect may be diſcovered; its particles diverge in ſeveral directions, diſplaying a moſt beautiful golden appearance. The metallic calces are, of all bodies, thoſe which are rendered phoſphoric with the greateſt difficulty. But even theſe may be ſcattered into a ſhower of red luminous particles by the electric ſtroke.

Norwich, Oct. 7, 1784.

POSTSCRIPT by the Rev. Dr. PRICE.

BY the *phoſphoric* force mentioned in the laſt paragraph of this paper, Mr. MORGAN appears to mean, not the force with which a phoſphoric body *emits*, but the force with which it *abſorbs* and *retains* light. This laſt force is proportioned to the degree of attraction between the phoſphoric body and light; and therefore muſt (as Mr. MORGAN obſerves) be *weakeſt* when it emits ſo freely the light it has imbibed as not to retain thoſe rays which adhere to it moſt ſtrongly. According to Mr. MORGAN's theory, theſe rays are thoſe which are leaſt refrangible. The obſervations and experiments in this paper ſeem to render this theory probable. It is, however, an objection to it, that the leſs refrangibility of rays ſeems to imply a leſs force of attraction between them and the ſubſtances which refract them; but it ſhould be conſidered, that, poſſibly, the force of coheſion, which unites the rays of light to bodies, may be a different power from that which refracts them.